

**CLOUDS AND THE EARTH'S RADIANT ENERGY SYSTEM
(CERES)**

CERES VALIDATION PLAN

**TIME INTERPOLATION AND SYNOPTIC FLUX
COMPUTATION FOR SINGLE AND MULTIPLE SATELLITES
(SUBSYSTEM 7.0)**

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CERES VALIDATION PLAN

7.0 TIME INTERPOLATION AND SYNOPTIC FLUX COMPUTATION FOR SINGLE AND MULTIPLE SATELLITES

7.1 INTRODUCTION

7.1.1 Measurement and science objective

The satellites that carry the CERES and Earth Observing System (EOS) instruments do not provide continuous spatial and temporal coverage of the Earth entire surface. In order to obtain accurate daily and/or monthly averages of the cloud and radiative parameters, accurate temporal modeling of their diurnal cycles is therefore essential. Using a state-of-the-art time and space averaging algorithm, CERES will improved the daily and monthly averages of the cloud and radiative parameters by producing accurate estimates of these quantities at the top of the atmosphere (TOA), within the atmosphere, and at the surface at 3-hourly GMT time intervals. These synoptic information can be used to improve the overall quality of the global cloud and radiation database and to aid the validation and testing of the global models.

7.1.2 Missions

The CERES instruments will be flown on multiple satellites, which include TRMM, EOS AM-1, and EOS PM-1, to provide the diurnal sampling necessary to obtain accurate monthly averages of the TOA radiative parameters.

7.1.3 Science data products

The CERES Subsystem 7.0 data algorithm produces the synoptic flux and cloud data product (SYN). This data product contains regional longwave (LW) and shortwave (SW) radiative fluxes for the surface, within the atmosphere, and TOA and cloud properties within the atmosphere. The data are synoptically computed at 3-hourly GMT intervals on a 1-degree equal angle grid, and are based on measurements from multiple EOS instruments. These synoptic information will then be used in CERES Subsystem 8 to compute accurate daily and monthly averages of the cloud and radiative parameters. There are 106 data parameters in the SYN data product. These include the synoptically averaged estimates of SW and LW flux at the TOA, within the atmosphere, and at the surface, the synoptically averaged estimates of cloud information within the atmosphere, the standard deviations of these estimates, their maximum and minimum value, and the scene type information. The complete list of data parameters is in the CERES Data Products Catalog.

In the next section, we outline the method adopted by the CERES Time Interpolation and Spatial Averaging (TISA) working group for validating the SYN data product. Section 7.3 and 7.4 concentrate on pre-launch and post-launch validations. Section 7.5 discusses the implementation of the validation data set in data production. A summary is given in Section 7.6.

7.2 VALIDATION CRITERION

7.2.1 Overall approach

The cornerstone of the CERES SYN algorithm is the incorporation of the geostationary satellite data into the time and space averaging scheme to account for the diurnal cycles of cloud and radiation fields which are insufficiently sampled by the CERES and EOS instruments. Specifically, the algorithm uses the geostationary data to assist in determining the shape of the diurnal cycle, but use the CERES observations as the absolute reference to anchor the more poorly calibrated geostationary data. The TOA LW flux is interpolated to the synoptic times in one of two ways. In method 1, the technique is identical to that used in ERBE-like processing (Subsystem 3.0). The second method is the geostationary-enhancement technique which uses narrowband geostationary and polar-orbiting satellite-derived information to provide a more accurate picture of the shape of the diurnal curve that is fit to the observation. Geostationary-enhancement technique is used whenever possible. Whenever narrowband data are not available or are inadequate, the TOA fluxes are derived using ERBE-like technique. Time interpolation of the clear-sky TOA LW flux is performed in a manner identical to the total-sky product. The averaging of SW data is not as straightforward as LW data. Unlike the LW flux case, the SW flux interpolation process is heavily dependent upon models. Time interpolation of cloud properties is performed using three main assumption. First, the properties of the four cloud pressure categories can be interpolated independently. Secondly, cloud properties for each region are interpolated independently from surrounding regions. Lastly, variation in cloud properties between CERES observation times can be modeled as linear. Atmospheric and surface fluxes at synoptic times are determined using radiative transfer models and synoptic inputs of cloud and atmospheric structure data within the atmosphere, and TOA fluxes. Additional information about this algorithm can be found in CERES ATBDs. The inputs to this subsystem include (1) atmospheric structures data (ASTR), (2) hourly gridded single satellite fluxes and clouds data (FSW), and (3) ancillary ISCCP radiances data (GEO). The outputs are the synoptic flux and cloud data (SYN).

The validation of this subsystem is an integral part of the CERES system. The purpose of this validation is to thoroughly test the subsystem and detect possible problems or errors. The overall approach to validating the SYN data product follows that outlined for the ERBE-like data product (Subsystem 3.0). This includes the validation of both the Subsystem 7.0 science algorithms and their associated science data product. Details of this approach can be found in the validation plan of Subsystem 3 and will not be repeated here. In order to conserve resources, the CERES TISA working group will not be validating every data parameter listed in the SYN science products. Instead, the validation is only performed for a set of emphasized parameters. These data parameters will include:

- (a) LW and SW TOA all-sky flux,
- (b) LW and SW TOA clear-sky flux,
- (c) all-sky window radiance,

- (d) LW and SW surface flux,
- (e) all-sky atmospheric flux at tropopause and 500-mb surface,
- (f) cloud amount,
- (g) cloud particle size,
- (h) cloud liquid and ice water path,
- (i) cloud emittance and optical depth, and
- (j) cloud height and thickness.

7.2.2 Sampling requirements

In order to validate SYN data product, TISA working group will require a minimum of one year of data from each of the CERES satellites. Additional data months are also required to perform data consistence test between different satellites (i.e., TRMM against AM, TRMM against PM, and AM against PM).

7.2.3 Measure of success

Reliable estimates of the uncertainties in the monthly mean data parameters due to time and space averaging processes can be obtained from limited case studies that are currently underway. These error estimates are given in Table 1 and 2 below. When applicable, estimates are given for both clear-sky and all-sky conditions. These tables show the best estimates of the accuracy goal currently available for Subsystem 7. However, these accuracy values will be updated by TISA working group as more information becomes available.

In order to approach the validation activity in a systematic matter, the CERES science team has adopted a two-steps process for validating this subsystem. This process can be broken down into the pre-launch and the post-launch validation. The details of these validations are outlined in the next two sections.

7.3 PRE-LAUNCH ALGORITHM TEST/DEVELOPEMENT ACTIVITIES

The pre-launch objective is to validate methods and algorithms. The procedures for the pre-launch validation activities are already given in Subsystem 3 and will not be repeated here. Instead, we concentrate on the description of the pre-launch validation activities and data set.

7.3.1 Field experiments and studies

The verification of the surface and atmospheric fluxes and the cloud product information can only be done using independent data obtained from intensive field experiments and/or special validation data sets. TISA working group is working very closely with CERES Clouds and SARB working groups during the pre-launch period to define suitable data sets for testing of these SYN algorithms. Examples of intensive field experiments that is currently being used to verify the quality of the pre-launch algorithm are the TOGA/COARE cloud and radiation data derived from GMS satellite, ARM cloud and radiation data derived from CAGEX and GOES satellite, ASTEX cloud and radiation data derived from METEOSAT satellite, and cloud and radiation data derived

during the ARESE experiment. Examples of special validation data include clouds and radiation data derived from the special Pathfinder data product and special high temporal resolution data derived from GOES satellite. A special validation output product will be produced to aid this validation process. This product will contain the following items:

- (a) Time series plots of cloud and radiation parameters over a pre-selected set of validation regions, latitude zone, and the globe.
- (b) Zonal and global averaged monthly mean images of these parameters.
- (c) Two dimensional error analysis results of the data product (if available).

The pre-selected set of validation regions includes (a) the validation sites from Subsystem 3 (see table 2 in Subsystem 3), (b) class 1 and 2 sites from Subsystem 5 (see table 1 and 2 from Subsystem 5), and (c) additional sites located at different universities (i.e., University of Utah, University of Miami, and Pennsylvania State University). These special validation regions which cover a wide range of climatic locations will be useful in testing the overall robustness of the SYN algorithm in handling data for various scene types and cloudiness conditions.

7.3.2 Operational surface networks

Operational surface networks are required for validation of the surface radiation fields. These networks are outlined in Subsystem 5 and will not be repeated here.

7.3.3 Existing satellite data

Many of pre-launch algorithm activities for testing the TOA fluxes and cloud information have already been performed using limited historical ERBE TOA scanner data and matching narrow-band geostationary information. Some of these results are given in the CERES ATBDs and in the CERES science team meeting. Additional tests based on CERES system-wide end-to-end pre-launch simulation of the Release 1 algorithm has been scheduled for this summer using inputs from existing ERBE TOA scanner data and ISCCP B3 data set. These activities will be used to initially check the quality of these TOA TISA algorithms, verify improvements in sampling error, and validate algorithm I/O and operation. Questions concerning software and system-wide problems will be addressed. In addition, the data processing system will be tested for interface compatibility with other CERES subsystem. Timing tests will be performed to define future scheduling requirements.

7.4 POST-LAUNCH ACTIVITIES

Post-launch validation concentrates on examination and verification of the CERES results. Specifically, the main purpose is to determine whether the results are qualitatively acceptable and agree reasonably well with expected quantitative results derived from other independent data sources. The procedures for the post-launch validation activities were given in Subsystem 3 and will not be repeated here. Instead, we concentrate on the description of the post-launch validation

data set.

7.4.1 Planned field activities and studies

Independent data sets from intensive field experiments are needed for post-launch validation of the SYN data product. Working in conjunction with CERES Clouds and SARB working group, the TISA working group plans to acquire long term record of cloud and radiation data from a number of intensive field experiments. This includes cloud and radiation data obtained from class 1 sites (i.e., ARM/Southern Great Plains (SGP), ARM/Tropical Western Pacific (TWP) and ARM/North Slope of Alaska (NSA)), future TOGA, FIRE, and UAV experiments. In addition, long term record of surface observations from class 2 sites, including Walker Tower, Boulder Tower, NOAA sites, and Baseline Surface Radiation Networks (BSRN) sites will also be used to validate surface radiation parameters. Additional information about these surface sites can be found in the CERES SARB validation plan (Subsystem 5).

7.4.2 New EOS-target coordinated field campaigns

N/A

7.4.3 Needs for other satellite data

Independent data sets from special validation data products are needed for post-launch validation of the SYN data product. Specifically, the CERES TISA working group plans to acquire data for every 3-month period, the 1-hourly (if available) and 3-hourly narrowband geostationary data (i.e., GOES-8, GOES-9, METEOSAT, and GMS) as the primary source of validation data set for TOA fluxes. In order to facilitate intercomparison between the two data sets, the narrowband radiances on the geostationary satellites will be converted to broadband fluxes using narrowband-to-broadband conversion relationships. In addition, TISA will also be acquiring data, if available, from the ERBE, ScaRaB, and the new European Geostationary Earth Radiation Budget (GERB) for direct comparison with CERES TOA fluxes.

7.4.4 Measurement needs (in situ) at calibration/validation sites

Special in situ measurement of cloud and radiation parameters are needed at validation sites to verify the SYN products. Details of these measurements can be found in the validation plan for Subsystem 4 (Clouds products) and 5 (surface and atmospheric radiation product) and will not be repeated here.

7.4.5 Needs for instrument development

N/A

7.4.6 Geometric registration site

N/A

7.4.7 Intercomparisons

After the launch of the EOS AM-1 and the EOS PM-1 satellite, the new CERES radiation data set can be validated by comparison with special validation data products from TRMM satellite. Furthermore, EOS AM-1 can be used to validate EOS PM-1.

7.5 IMPLEMENTATION OF VALIDATION RESULTS IN DATA PRODUCTION

7.5.1 Approach

The procedures for pre-launch and post-launch validation of this subsystem were outlined in the previous section. The results of these validations should, in general, lead to further improvement in the quality of the CERES data set. Major problems discovered after data production will be recorded and techniques for resolving problems will be developed. Correction will be implemented for the CERES data reprocessing.

7.5.2 Role of EODSIS

EODSIS will provide special processing of SYN data products from regions containing validation sites.

7.5.3 Plans for archival of validation data

The results of the validation and their associated problems will be stored at the NASA Langley Research Center. The user community can access these information either through an anonymous FTP account or through the use of World Wide Web browser technology.

7.6 SUMMARY

This document describes a plan for validating the CERES SYN data product. The validation plan is broken up into two stages; the pre-launch and the post-launch stage. Minimum of one year of data from each of the CERES satellites will be required to validate the data products. The validation efforts will be concentrated on a set of emphasized parameters. A set of special validation regions will be used to identify and to record problematic areas associated with the SYN data product. EODSIS will provide special processing of CERES SYN data product for regions containing these validation sites.

Working very closely with the CERES clouds and SARB working group, TISA working group has completed some of the pre-launch testing of the SYN algorithm. The results of these activities are reported in the CERES ATBDs and in the CERES science team meeting. Additional pre-launch tests based on CERES system-wide end-to-end simulation are being scheduled in the summer. The post-launch validation will concentrate on using geostationary data to verify TOA radiative parameters. Secondary data sets, if available, will be obtained from ERBE, ScaRaB, and

GERB for direct TOA flux comparison. Validation of cloud and surface and in-the-atmosphere fluxes will require independent data sets from intensive field experiments. Working in conjunction with CERES Clouds and SARB working groups, the TISA working group plans to acquire long term record of cloud and radiation data from a number of intensive field experiments. This includes cloud and radiation data obtained from class 1 sites (i.e., ARM/Southern Great Plains (SGP), ARM/Tropical Western Pacific (TWP) and ARM/North Slope of Alaska (NSA)), future TOGA, FIRE, and UAV experiments. In addition, long term record of surface observations from class 2 sites, including Walker Tower, Boulder Tower, NOAA sites, and Baseline Surface Radiation Networks (BSRN) sites will also be used to validate surface radiation parameters (see Subsystem 5 for additional information). The results of the validation and their associated problems will be stored at the NASA Langley Research Center. The user community can access these information either through an anonymous FTP account or through the use of World Wide Web browser technology.

Table 1: Accuracy Estimates for Synoptic 3-hourly Radiative Parameters.

Parameter	Clear-sky Bias Error	Clear-sky RMS Error	All-sky Bias Error	All-sky RMS Error
TOA SW _{up} (Watts/m ²)	2	30	2	20
TOA LW _{up} (Watts/m ²)	1	20	1	20
Surface SW _{up} (Watts/m ²)	2	10	2	10
Surface SW _{down} (Watts/m ²)	20	30	20	30
Surface LW _{up} (Watts/m ²)	2	15	2	15
Surface LW _{down} (Watts/m ²)	8	15	12	20
Atmospheric SW _{up} (Watts/m ²)	4	30	4	30
Atmospheric SW _{down} (Watts/m ²)	8	10	8	10
Atmospheric LW _{up} (Watts/m ²)	5	15	5	15
Atmospheric LW _{down} (Watts/m ²)	3	5	3	5

Table 2: Accuracy Estimates for Synoptic 3-hourly Cloud Product.

Parameter	RMS Error
Cloud amount	25%
Cloud particle size	80%
Cloud liquid/ice water path	>100%
Cloud emittance	30%
Cloud visible optical depth	80%
Cloud height	20%

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DATA PRODUCTS/PARAMETERS

- TOA, in-the-atmosphere, and surface flux and clouds layer information in the atmosphere at 3-hourly GMT time resolution over the whole globe.

MISSION

- TRMM, EOS AM-1, and EOS PM-1.

APPROACH

- Complete pre-launch science studies for improving and verifying TISA methods.
- Verify input/output operations and interface compatibility with other subsystems.
- Compare results with validation data set.

PRELAUNCH

- Complete validation of the science algorithm.
- Finish testing of the data processing system.
- Verify TOA results with historical ERBE TOA scanner data.
- Perform case study using geostationary data, CAGEX, and TOGA data to verify science algorithm.
- Validate data processing system using CERES end-to-end simulation.

POST-LAUNCH

- Primary comparison of TOA fluxes with geostationary data using narrowband-to-broadband conversion technique.
- Secondary direct verification of TOA fluxes (if available) with ERBE WFOV results, ScaRaB data, and GERB data.
- Comparison with cloud and radiation data collected from intensive field experiments (i.e., TOGA, FIRE, CAGEX, ARM/TWP, ARM/NSA, and UAV experiment).
- Comparison with cloud and radiation data collected from special validation regions; including class 1 and class 2 sites (i.e., Walker Tower, Boulder Tower, NOAA sites, and BSRN sites).
- Additional intercomparison between TRMM, EOS AM-1, and EOS PM-1 data.

EOSDIS

- Special processing of CERES SYN data products containing validation sites.